

## IMAGE CAPTURING APPARATUS AND METHOD THEREFOR

### BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

This invention relates to an image capturing apparatus and a method therefor, and more particularly, is suitably applied, for example, to a video camera.

### DESCRIPTION OF THE RELATED ART

Conventionally, there is a video camera which composes a plurality of images captured with different amounts of exposure to produce an image having a wide dynamic range (i.e., an image which represents from a light region to a dark region).

A method of capturing a plurality of images with different amounts of exposure as mentioned may employ, as an imager device, a solid-state imager device (CCD: Charge Coupled Device), and involves adjusting an electronic shutter, which is a function possessed by the CCD, to change the exposure time to capture a plurality of images in a time division manner. In this method, a charge is accumulated and read in an arbitrary field period in a manner similar to a normal imaging operation, and subsequently a charge is again accumulated and read utilizing a vertical blanking period to capture two different images with different exposure times within one field period.

Also, as illustrated in Fig. 1, another method utilizes Neutral Density (ND) filters 3 having different transmittivities placed on respective pixels of an imager device 1 to capture an image which is spatially divided into segments having different amounts of exposure. Further, as illustrated in Fig. 2, another method involves providing a plurality of imager devices 5A, 5B, and capturing a plurality of images without reducing the spatial resolution by disposing ND filters in front of the respective imager devices, for example, placing an ND filter 7 in front of the imager device 5B, to give different transmittivities.

The method of capturing a plurality of images having different amounts of exposure in a time division manner is capable of producing an image of higher resolution as compared with the method of capturing a plurality of images having different exposure amounts in a spatial division manner, and is simpler in structure and lower in cost as compared with the method of capturing a plurality of images having different amounts of exposure using a plurality of imager devices. It can therefore be said that this image capturing method is better than the other two.

However, since the method of capturing a plurality of images having different amounts of exposure in a time division manner captures respective images having different amounts of exposure at different times, misregistration between the respective images, if caused by unintended movements of hands or the like, would result in a problem of a degraded image quality on a resulting composite

image produced by composing the captured images having different amounts of exposure due to the misregistration on the composite image.

Referring now to Figs. 3A and 3B, explanation will be given of how such misregistration between respective images causes a degraded image quality of a composite image. Fig. 3A one-dimensionally shows an image captured with long time exposure; and Fig. 3B one-dimensionally shows an image captured with short time exposure, where misregistration equal to a length D occurs between the two images. When these two images are composed, disturbed image portions will be produced near the edges, as a composite image shown in Fig. 3C.

#### SUMMARY OF THE INVENTION

In view of the foregoing, an object of this invention is to provide an image capturing apparatus and a method therefor which are capable of producing a natural composite image corresponding to an object to be imaged.

The foregoing object and other objects of the invention have been achieved by the provision of an image capturing apparatus for capturing a plurality of images with different amounts of exposure to compose the images into a single composite image, comprising misregistration amount detecting means for detecting the amounts of misregistration of respective images except for a reference image, wherein the reference image is selected from the plurality

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of images, with respect to the reference image, misregistration correcting means for correcting misregistration of the respective images except for the reference image with respect to the reference image based on the misregistration amounts, and image composing means for composing the reference image and all of the respective misregistration corrected images except for the reference images.

A misregistration amount of each of the images except for the reference image is detected with respect to the reference image, misregistration of each of the images except for the reference image with respect to the reference image is corrected on the basis of the misregistration amount, and then the reference image and the respective misregistration corrected images except for the reference image are composed, thereby making it possible to avoid a degraded image quality which would otherwise be produced when a plurality of images are composed without correction.

The nature, principle and utility of the invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings in which like parts are designated by like reference numerals or characters.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a schematic diagram used for explaining exposure amount control based on spatial division;



Fig. 14 is a schematic diagram used for explaining histogram equalization;

Fig. 15 is a block diagram illustrating the configuration of a video camera according to a second embodiment;

Fig. 16 is a block diagram illustrating the configuration of a misregistration amount detector;

Fig. 17 is a schematic diagram used for explaining the classification of zero-cross points;

Fig. 18 is a block diagram illustrating the configuration of a video camera according to a third embodiment;

Fig. 19 is block diagram illustrating the configuration of a misregistration amount detector;

Figs. 20A and 20B are diagrams showing a feature point search range;

Fig. 21 is a block diagram illustrating the configuration of a video camera according to a fourth embodiment;

Fig. 22 is a schematic diagram used for explaining an example of a color filter arrangement in a single-plate color camera;

Fig. 23 is a schematic diagram used for explaining an output signal of the single-plate color camera;

Figs. 24A and 24B are schematic diagrams used for explaining interpolation processing;

Fig. 25 is a schematic diagram used for explaining a feature point scanning range;

Fig. 26 is a block diagram illustrating the configuration of

a misregistration amount detector according to another embodiment;

Fig. 27 is a schematic diagram used for explaining a confidence map;

Fig. 28 is a block diagram illustrating the configuration of a misregistration amount detector according to another embodiment;

Fig. 29 is a block diagram illustrating the configuration of a misregistration amount detector according to another embodiment; and

Fig. 30 is a schematic diagram used for explaining an example of a color filter arrangement in a single-plate color camera.

#### DETAILED DESCRIPTION OF THE EMBODIMENT

Preferred embodiments of this invention will be described with reference to the accompanying drawings:

##### (1) First Embodiment

In Fig. 4, a video camera, the configuration of which is generally designated by reference numeral 10, is adapted to capture two images having different amounts of exposure in a time division manner by use of a solid-state imager device (CCD: Charge Coupled Device) 12. As shown in Fig. 5, the CCD 12 accumulates and reads a charge in an arbitrary field period, in a manner similar to normal imaging, and subsequently accumulates and reads a charge again utilizing a vertical blanking period, to produce two images with different times of exposure within one field period. In this way, the CCD 12 produces two images with





$$g = \frac{T_{long}}{T_{short}} \quad \dots (2)$$

where  $T_{long}$  is an exposure time for the long time exposure, and  $T_{short}$  is an exposure time for the short time exposure. For reference,  $xS1(i, j)$  represents the value of a pixel at a position  $(i, j)$  on the short time exposed image  $xS1$ .

The limiter 25 is provided for defining an upper limit for each pixel value on the short time exposed image  $xS2$  which has been subjected to a gain correction. As given by the following equation:

$$xS3(i, j) = \begin{cases} xS2(i, j) & \dots xS2(i, j) \leq Tup \\ Tup & \dots xS2(i, j) > Tup \end{cases} \quad \dots (3)$$

within respective pixels forming the short time exposed image  $xS2$ , a pixel value equal to or lower than a predetermined threshold value is outputted as it is, while a pixel value exceeding the predetermined threshold value is replaced with the threshold value  $T_{up}$  which is outputted in place to produce a short time exposed image  $xS3$  which is then sent to a misregistration amount detector 27.

The limiter 18 in turn is provided for defining an upper limit for each pixel value on the long time exposed image  $xL1$ . As is the case with the limiter 25, within respective pixels forming the long time exposed image  $xL1$ , a pixel value equal to or lower

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than a predetermined threshold value is outputted as it is, while a pixel value exceeding the predetermined threshold value is replaced with the threshold value  $T_{up}$  which is outputted in place to produce a long time exposed image xL2 which is then sent to a misregistration amount detector 27.

As shown in Fig. 6, the misregistration amount detector 27 detects the amount of misregistration between the long time exposed image xL2 and the short time exposed image xS3 as a two-dimensional vector  $d=(dx,dy)$  which is sent to the misregistration corrector 23. Here, dx represents a horizontal component of the amount of misregistration; and dy a vertical component of the same.

As illustrated in Fig. 7, the misregistration amount detector 27 inputs the long time exposed image xL2 supplied from the limiter 18 to a feature point extractor 30A, and inputs the short time exposed image xS3 supplied from the limiter 25 to a feature point extractor 30B. The feature point extractor 30A extracts feature points from the long time exposed image xL2 to produce a feature point image pL1 which is sent to a memory 32A. The feature point image pL1 is a binary image in which each pixel has a value "0" or "1," with the pixel value "1" indicating that a corresponding pixel on the long time exposed image xL2 is a feature point, and the pixel value "0" indicating that a corresponding pixel is not a feature point. Employed herein as the feature point is, for example, an edge point at which a spatially abrupt change is present within the long time exposed

image xL2.

Similarly, the feature point extractor 30B extracts feature points from the short time exposed image xS3 to produce a feature point image pS1 which is sent to a memory 32B. Similar to the feature point image pL1, the feature point image pS1 is a binary image in which each pixel has a value "0" or "1," with the pixel value "1" indicating that a corresponding pixel on the long time exposed image xS3 is a feature point, and the pixel value "0" indicating that a corresponding pixel is not a feature point.

The feature point extractors 30A, 30B are similar in configuration, so that the feature point extractor 30A will only be described herein with respect to the circuit configuration with reference to Fig. 8. The feature point extractor 30A inputs the long time exposed image xL2 supplied from the limiter 18 (Fig. 4) to a second-order differentiation type filter 35. The second-order differentiation type filter 35 employs, for example, the following equation referred to as Laplacian G:

$$\nabla^2 G(h,k) = \frac{-1}{\pi\sigma^2} \left[ 1 - \frac{h^2 + k^2}{2\sigma^2} \right] e^{-\frac{h^2 + k^2}{2\sigma^2}} \quad \dots\dots (4)$$

$$h_{min} \leq h \leq h_{max}$$

$$k_{min} \leq k \leq k_{max}$$

and performs a convolutional operation by the following equation:

$$xL3(i, j) = \sum_{\substack{h \min \leq h \leq h \max \\ k \min \leq k \leq k \max}} x(i-h, j-k) \times \nabla^2 G(h, k) \quad \dots \quad (5)$$

to find a second-order differentiated image  $x_{L3}$  which is sent to a binarizer 37. Here,  $\sigma$  is a preset constant, and the larger the  $\sigma$  is, the more apt an edge of a lower frequency component to be detected. Also,  $h_{\min}$ ,  $h_{\max}$ ,  $k_{\min}$ ,  $k_{\max}$  are constants for defining the span of the filter which implements Laplacian G.

The binarizer 37 outputs the value "1" when a pixel value is "0" or more and the value "0" when the pixel value is less than "0" at each of pixels on the second-order differentiated image xL3, to produce a binary image xL4 which is sent to a boundary point detector 39. The binary point detector 39 applies the binary image xL4 with neighborhood processing as given by the following equation:

$$p(i, j) = \begin{cases} 1 \cdots b(i, j) \neq b(i + di, j + dj) \\ \quad -1 \leq di, dj \leq 1 \\ 0 \cdots \quad \text{others} \end{cases} \quad \text{..... (6)}$$

to extract boundary points on a binary pattern to produce a feature point image pL1 which is sent to the memory 32A (Fig. 7). Stated another way, the boundary point detector 39 outputs the value "1" only when pixels having different values exist within a

neighborhood region, regarding that a feature point is present at a central position among them. The feature point extracted in this way is referred to as a zero-cross point which means a central point in an edge pattern at which the pixel value presents an abrupt change, as shown in Fig. 9.

Turning back to Fig. 7, the memory 32A temporarily accumulates the feature point image pL1, and subsequently reads the feature point image pL1 at a predetermined timing to send it to a confidence level calculator 45. Similarly, the memory 32B temporarily accumulates the feature point image pS1, and subsequently reads the feature point image pS1 at a predetermined timing to send it to the confidence level calculator 45.

The confidence level calculator 45 calculates a confidence level which indicates the amount of correct misregistration for each of a plurality of previously provided misregistration amount candidates  $dn=(dxn, dyn)$  based on the feature point images pL1, pS1. The misregistration amount candidate dn may be given by inequalities as shown below, for example, by selecting a maximum value for the amount of misregistration which may be produced:

$$\begin{aligned} -dx_{\max} &\leq dxn \leq dx_{\max} \\ -dy_{\max} &\leq dyn \leq dy_{\max} \end{aligned} \quad \dots (7)$$

where  $dx_{\max}$  indicates the absolute value of a maximum misregistration amount in the horizontal direction; and  $dy_{\max}$

indicates the absolute value of a maximum misregistration amount in the vertical direction.

Here, how to calculate the confidence level for each misregistration amount candidate  $dn$  will be explained in a specific manner. The confidence level calculator 45 first scans the feature point image  $pL1$  in an order as indicated in Fig. 10 to detect a position at which the pixel value indicates "1," i.e., the position of a feature point. Assuming that the position of a pixel corresponding to a feature point of interest in the feature point image  $pL1$  is at  $(i,j)$  (Fig. 11A), the confidence level calculator 45 examines whether or not a feature point exists on each of positions  $(i+dxn, j+dyn)$  on the feature point image  $pS1$ , corresponding to a plurality of misregistration amount candidates  $dn=(dxn, dyn)$ . When the misregistration amount candidate  $dn$  is given by the inequalities such as those (7) mentioned above, a feature point search range on the feature point image  $pS1$  is represented by an area  $R$  as shown in Fig. 11B.

As a result, when the confidence level calculator 45 detects that a feature point exists at a position  $(i+dxn, j+dyn)$  on the feature point image  $pS1$ , the confidence level calculator 45 increments the confidence level for the misregistration amount candidate  $dn=(dxn, dyn)$  in accordance with the following equation:

$$cmap(dn) = cmap (dn) + 1 \quad \dots\dots (8)$$

where  $\text{cmap}(\text{dn})$  is a confidence map for integrating the confidence level for each misregistration amount candidate, and is previously initialized as given by the following equation:

$$\text{cmap}(\text{dn}) = 0 \quad \text{for all dn} \quad \dots\dots (9)$$

In this way, the confidence level calculator 45 accumulates the confidence levels for all feature points on the feature point image pL1 to produce the confidence map  $\text{cmap}(\text{dn})$  ( $n=0, 1, 2, \dots$ ) which is sent to a maximum value detector 47.

The maximum value detector 47 detects a misregistration value candidate  $d_{\text{max}}$  having a maximum confidence level within the confidence map  $\text{cmap}(\text{dn})$ , and sends this as a true misregistration amount  $d$  to the misregistration amount corrector 23 (Fig. 4). For reference, if a plurality of misregistration amount candidates  $\text{dn}$  having the same confidence level exist, the maximum value detector 47 selects the misregistration amount candidate  $\text{dn}$  that exhibits the smallest magnitude  $|\text{dn}|$  of the misregistration amount found by the following equation:

$$|\text{dn}|^2 = \text{dxn}^2 + \text{dyn}^2 \quad \dots\dots (10)$$

Also, when the maximum value  $d_{\text{max}}$  of a detected confidence level is lower than a predetermined threshold value, i.e., does not satisfy a condition given by the following equation:

$$c_{\max} > a \times T_{\text{count}}$$

..... (11)

$$0.0 \leq a \leq 1.0$$

the maximum value detector 47 sets  $d=(0,0)$  so as not to perform a misregistration correction, regarding that a sufficiently confident misregistration amount cannot be available. In the above equation,  $a$  is a coefficient for determining a threshold value, and is a preset value, and  $T_{\text{count}}$  indicates the total number of feature points extracted from the long time exposed image  $xL2$ .

Turning back to Fig. 4, the misregistration corrector 23 translates the short time exposed image  $xS1$  supplied from the memory 16 in accordance with the following equation:

$$xS4(i,j) = xS1(i-dx,j-dy)$$

..... (12)

based on the misregistration amount vector  $d$  detected by the misregistration amount detector 27, to correct the misregistration with respect to the long time exposed image  $xL1$ , and sends a resultant short time exposed image  $xS4$  to the image composer 20.

The image composer 20 composes the long time exposed image  $xL1$  supplied from the memory 14 and the short time exposed image  $xS4$  corrected by the misregistration corrector 23 to produce a single composite image  $x1$  having a wider dynamic range which is sent to a dynamic range compressor 49.

A method of composing these long time exposed image  $xL1$  and



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short time exposed image xS4 may involve accumulating a coefficient corresponding to the ratio of the amounts of exposure, with which respective images were captured, for each of the images, and subsequently outputting the respective images in turn according to thresholding to produce the composite image x1. In the following, the image composing method implemented by the image composer 20 will be explained in a specific manner with reference to Fig. 12. In Fig. 12, the horizontal axis represents the amount of incident light on the CCD 12, and the vertical axis represents a signal level of an output signal delivered from the CCD 12, i.e., a pixel level of a captured image.

As shown in Fig. 12, the long time exposed image xL1 is represented by a straight line having a large slope, but exhibits a constant signal level of the output signal due to saturation of the CCD 12 when the amount of incident light is equal to or larger than a predetermined level  $T_{up}$ . The short time exposed image xS4 in turn has a small slope, and the output signal delivered from the CCD 12 saturates with a larger amount of incident light than the long time exposed image xL1.

Consequently, the image composer 20 first accumulates the coefficient  $g$  calculated by the aforementioned equation (2) for the output signal corresponding to the short time exposed image xS4 to match the slope of the straight line portion with that of the long time exposed image xL1. Subsequently, referring to the output signal corresponding to the long time exposed image xL1,



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processing capabilities of a transmission system, a display, a recorder and so on, not shown, disposed at stages subsequent thereto, and outputs a resulting compressed composite image  $y_1$  to the outside. More specifically, the dynamic range compressor 49 employs a method of converting a pixel level of each pixel in the composite image  $x_1$  using a function having an input/output relationship as shown in Fig. 13 (hereinafter referred to as the "level conversion function"), as a method of compressing the composite image  $x_1$  having a wide dynamic range (hereinafter referred to as the "level conversion").

In Fig. 13, the horizontal axis represents a pixel level  $l$  of the inputted composite image  $x_1$ , and the vertical axis represents a pixel level  $T(l)$  of the compressed composite image  $y_1$  which has undergone the level conversion processing.  $Linmax$  indicates a maximum pixel level that can be taken by each pixel in the inputted composite image  $x_1$ , and  $Loutmax$  indicates a maximum pixel level which can be taken by each pixel in the compressed composite image  $y_1$  outputted from the dynamic range compressor 49. In this level conversion, the full dynamic range is compressed, while ensuring the contrast in low and intermediate level ranges at the cost of the contrast in a high level range.

Alternatively, the method of compressing the composite image  $x_1$  having a wide dynamic range may involve adaptively changing the level conversion function in accordance with the frequency distribution of the pixel levels on the composite image  $x_1$ . As a



compression of the full dynamic range while ensuring the contrast in a region composed by levels which present a high appearance frequency (a region having a large area).

With the foregoing configuration, the misregistration amount detector 27 extracts feature points respectively from a long time exposed image xL2 and a short time exposed image xS3, captured with different exposure times, detects the misregistration amount candidate presenting the highest confidence level within a plurality of previously provided misregistration amount candidates dn based on the positional relationship of respective feature points extracted from the long time exposed image xL2 and respective feature points extracted from the short time exposed image xS3, and sends the detected misregistration amount candidate as a true misregistration amount d to the misregistration corrector 23.

The misregistration corrector 23 corrects the misregistration of the short time exposed image xS1 with respect to the long time exposed image xL1 based on the misregistration amount d sent from the misregistration amount detector 27, and sends a resultant short time exposed image xS4 to the image composer 20. The image composer 20 composes the long time exposed image xL1 and the misregistration corrected short time exposed image xS4 to produce a single composite image x1 having a wide dynamic range.

By thus composing the long time exposed image xL1 and the short time exposed image xS1 after correcting the misregistration

therebetween, the image quality will never be degraded near the edges as observed in a composite image which would be composed with misregistration present between two images.

According to the configuration described above, the misregistration of the short time exposed image xS1 is corrected with respect to the long time exposed image xL1, and then the long time exposed image xL1 and the misregistration corrected short time exposed image xS4 are composed to produce the composite image x1 to avoid a degraded image quality which would otherwise be found when two images are composed without correction, thereby making it possible to produce a natural composite image suitable for an object to be imaged.

## (2) Second Embodiment

In Fig. 15, in which parts corresponding to those in Fig. 4 are designated by the same reference numerals, a video camera according to a second embodiment, generally designated by reference numeral 60, is configured in a similar manner to the video camera 10 according to the first embodiment except for the configuration of a misregistration amount detector 62.

Fig. 16, in which parts corresponding to those in Fig. 7 are designated by the same reference numerals, illustrates the configuration of the misregistration amount detector 62. This misregistration amount detector 62 is adapted to extract four types of feature points. More specifically, zero-cross points as

previously shown in Fig. 9 are classified into feature points P1 to P4 as shown in Fig. 17, based on the signs of pixel values possessed by pixels surrounding the respective zero-cross points.

The following description will be directed to a misregistration amount detection performed by the misregistration amount detector 62. The misregistration amount detector 62 inputs a long time exposed image xL2 supplied from the limiter 18 to feature point extractors 64A<sub>1</sub> to 64A<sub>4</sub>, and inputs a short time exposed image xS3 supplied from the limiter 25 to feature point extractors 64B<sub>1</sub> to 64B<sub>4</sub>.

The feature point extractor 64A<sub>1</sub> extracts only feature points P1 from the long time exposed image xL2 to produce a feature point image pL11 which is sent to a memory 66A<sub>1</sub>. The feature point extractor 64B<sub>1</sub> in turn extracts only the feature point P1 from the short time exposed image xS3 to produce a feature point image sP11 which is sent to a memory 66B<sub>1</sub>. Similarly, the feature point extractors 64A<sub>2</sub> to 64A<sub>4</sub> extract only the feature points P2 to P4 corresponding thereto from the long time exposed image xL2 to produce feature point images pL12 to pL14 which are sent to corresponding memories 66A<sub>2</sub> to 66A<sub>4</sub>, respectively. The feature points extractors 64B<sub>2</sub> to 64B<sub>4</sub> in turn extract only feature points P2 to P4 corresponding thereto from the short time exposed image xS3 to produce feature point images pS12 to pS14 which are sent to corresponding memories 66B<sub>2</sub> to 66B<sub>4</sub>, respectively.

The memory 66A<sub>1</sub> temporarily stores the feature point image





maximum value detector 47. The maximum value detector 47 detects a misregistration amount candidate  $d_{\max}$  having a maximum confidence level within the confidence map  $\text{cmap}(dn)$ , and sends this as a true misregistration amount  $d$  to a misregistration amount corrector (Fig. 15).

In the foregoing configuration, the misregistration amount detector 62 extracts four types of feature points P1 to P4, respectively from the long time exposed image xL2 and the short time exposed image xS3, captured with different exposure times, and calculates the confidence level for a plurality of misregistration amount candidates  $dn$  for each type of the extracted feature points. Then, the misregistration amount detector 62 calculates the sum of the confidence levels calculated for each type of the feature points for each misregistration amount candidate  $dn$ , and detects the misregistration amount candidate  $dn$  having the highest confidence level within the thus calculated confidence levels for the plurality of misregistration amount candidates  $dn$ , and sends this as a true misregistration amount  $d$  to the misregistration corrector 23.

The misregistration corrector 23 corrects the misregistration of the short time exposed image xS1 with respect to the long time exposed image xL1 based on the misregistration amount  $d$  sent from the misregistration amount detector 27, and sends a resultant short time exposed image xS4 to the image composer 20. The image composer 20 composes the long time exposed image xL1 and the

misregistration corrected short time exposed image xS4 to produce a single composite image x1 having a wide dynamic range.

By thus composing the long time exposed image xL1 and the short time exposed image xS1 after correcting the misregistration therebetween, the image quality will never be degraded near the edges as observed in a composite image which would be composed with misregistration present between two images.

According to the configuration described above, the misregistration of the short time exposed image xS1 is corrected with respect to the long time exposed image xL1, and then the long time exposed image xL1 and the misregistration corrected short time exposed image xS4 are composed to produce the composite image x1 to avoid a degraded image quality which would otherwise be found when two images are composed without correction, thereby making it possible to produce a natural composite image corresponding to an object to be imaged.

In addition, since plural types of feature points are extracted from the long time exposed image xL2 and the short time exposed image xS3 to detect the misregistration amount  $d$  using the thus extracted feature points of the plural types, the misregistration amount can be more accurately detected as compared with the misregistration amount detector 27 in the first embodiment.

### (3) Third Embodiment

In Fig. 18, in which parts corresponding to those in Fig. 4 are designated by the same reference numerals, a video camera, the configuration of which is generally designated by reference numeral 100, is configured in a manner similar to the video camera 10 according to the first embodiment except for the configuration of horizontal integrators 102, 103, vertical integrators 104, 105, misregistration amount detectors 108, 109, a misregistration corrector 111.

The video camera 100 supplies the horizontal integrator 102 and the vertical integrator 104 with a long time exposed image xL2 sent from the limiter 18, and supplies the horizontal integrator 103 and the vertical integrator 105 with a short time exposed image xS3 sent from the limiter 25. The horizontal integrator 102 integrates pixel values at respective vertical positions j of the long time exposed image xL2 in the horizontal direction in accordance with the following equation:

$$xLH1(j) = \sum_{i=0}^{N_x-1} xL2(i, j) \quad \dots\dots (17)$$

$$j=0, 1, 2, \dots, N_y-1$$

to produce a one-dimensional data array xLH1 which is sent to the misregistration amount detector 108. In equation (17),  $N_x$  and  $N_y$  are the numbers of pixels in the horizontal direction and in the

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$$xLV1(j) = \sum_{i=0}^{Ny-1} xL2(i, j) \quad \dots\dots (18)$$

to produce a one-dimensional data array xLV1 which is sent to the misregistration amount detector 109. Similarly, the horizontal integrator 103 produces a one-dimensional data array xSH1 from the short time exposed image xS3, and sends the one-dimensional data array xSH1 to the misregistration amount detector 108. Together with this, the vertical integrator 105 produces a one-dimensional data array xSV1 from the short time exposed image xS3, and sends the one-dimensional data array xSV1 to the misregistration amount detector 109.

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component dy to the misregistration corrector 111. Together with this, the misregistration amount detector 109 detects a horizontal component dx of the misregistration amount based on the one-dimensional data array xLV1 produced from the long time exposed image xL2 and the one-dimensional data array xSV1 produced from the short time exposed image xS3, and sends the horizontal component dx to the misregistration corrector 111.

It should be noted that the misregistration amount detectors 108, 109 are similar in configuration, so that the following description will be directed only to the configuration of the misregistration amount detector 109 with reference to Fig. 19. The misregistration amount detector 109 inputs the one-dimensional data array xLV1 produced from the long time exposed image xL2 to a feature point extractor 115A, and inputs the one-dimensional data array xSV1 produced from the short time exposed image xS3 to a feature point extractor 115B.

The feature point extractor 115A extracts feature points in the one-dimensional data array xLV1 to produce a one-dimensional feature point array pLV1 which is sent to a memory 117A. The feature point called herein is the zero-cross point shown in Fig. 9, and the one-dimensional data array xLV1 is an array of binary data each indicating whether or not a feature point exists at a position i. Similarly, the feature point extractor 115B extracts feature points in the one-dimensional data array xSV1 to produce a one-dimensional data array pSV1 which is sent to a memory 117B.



feature point of interest on the feature point array pLV1 is at i (Fig. 20A), the confidence level calculator 119 examines whether or not a feature point exists at a position i+dx on the feature point array pSV1, corresponding to a horizontal component dx of each of a plurality of misregistration amount candidates. When the horizontal component dx of the misregistration amount candidate is given by the inequality such as that (19) mentioned above, a feature point search range on the feature point array pSV1 is represented by an area R as shown in Fig. 20B.

As a result, when the confidence level calculator 119 detects that a feature point exists at a position i+dx on the feature point array pSV1, the confidence level calculator 119 increments the confidence level for the horizontal component dx of the misregistration amount candidate. In this way, the confidence level calculator 119 integrates the confidence levels for all feature points on the feature point array pLV1 to produce a confidence map cmap(dx<sub>n</sub>) (n=0, 1, 2, ....) which is sent to a maximum value detector 121. The maximum value detector 121 detects a horizontal component dx<sub>max</sub> of a misregistration amount candidate which has a maximum confidence level within the confidence map cmap(dx<sub>n</sub>), and sends this as a horizontal component dx of a true misregistration amount to the misregistration corrector 111 (Fig. 18).

Turning back to Fig. 18, the misregistration corrector 111 translates the short time exposed image xS1 based on the

horizontal component dx of the misregistration amount supplied from the misregistration amount detector 109 and the vertical component dy of the misregistration amount supplied from the misregistration amount detector 108 to correct the misregistration of the short time exposed image xS1 with respect to the long time exposed image xL1, and sends a resultant short time exposed image xS4 to the image composer 20.

In the foregoing configuration, the horizontal integrators 102, 103 integrate pixel values for each pixel array in the horizontal direction of a long time exposed image xL2 and a short time exposed image xS3, respectively, to produce one-dimensional vertical data arrays xLH1, xSH1 which are sent to the misregistration amount detector 108. Together with this, the vertical integrators 104, 105 integrate pixel values for each pixel arrays in the vertical direction of the long time exposed image xL2 and the short time exposed image xS3, respectively, to produce one-dimensional horizontal data arrays xLV1, xSV1 which are sent to the misregistration amount detector 109.

The misregistration amount detector 108 extracts feature points from the one-dimensional vertical data arrays xLH1, xSH1, detects a vertical component of the misregistration amount candidate presenting the highest confidence level within vertical components dyn of a plurality of previously provided misregistration amount candidates based on the positional relationship of the respective feature points in the one-



dimensional data array xLH1 and the respective feature points in the one-dimensional data array xSH1 extracted as mentioned, and sends this as a true misregistration amount dy to the misregistration corrector 111. Similarly, the misregistration amount detector 109 extracts feature points from the one-dimensional horizontal data arrays xLV1, xSV1, detects a misregistration amount dx based on the positional relationship of the respective feature points in the one-dimensional data array xLV1 and the respective feature points in the one-dimensional data array xSH1 extracted as mentioned, and sends the detected misregistration amount dx to the misregistration corrector 111.

The misregistration amount corrector 111 corrects the misregistration of the short time exposed image xS1 with respect to the long time exposed image xL1 based on the misregistration amounts dx, dy sent from the misregistration amount detectors 109, 108, and sends a resultant short time exposed image xS4 to the image composer 20. The image composer 20 composes the long time exposed image xL1 and the misregistration corrected short time exposed image xS4 to produce a signal composite image x1 having a wide dynamic range.

By thus composing the long time exposed image xL1 and the short time exposed image xS1 after correcting the misregistration therebetween, the image quality will never be degraded near the edges as observed in a composite image which would be composed with misregistration present between two images.

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According to the configuration described above, the misregistration of the short time exposed image xS1 is corrected with respect to the long time exposed image xL1, and then the long time exposed image xL1 and the misregistration corrected short time exposed image xS4 are composed to produce the composite image x1 to avoid a degraded image quality which would otherwise be found when two images are composed without correction, thereby making it possible to produce a natural composite image corresponding to an object to be imaged.

Also, by detecting the misregistration amount of the short time exposed image xS1 with respect to the long time exposed image xL1 for each of the horizontal component and the vertical component, it is possible to further reduce the amount of operations and the circuit scale associated with the detection of misregistration.

#### (4) Fourth Embodiment

In Fig. 21, in which parts corresponding to those in Fig. 4 are designated by the same reference numerals, a video camera according to a fourth embodiment, generally designated by reference numeral 120, comprises a color array filter as shown in Fig. 22 (complementary color diced filter) positioned in front of a CCD 122 to capture a color image through this filter to produce a long time exposed image xL10 and a short time exposed image xS10 represented by output signals, as shown in Fig. 23, in which a

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misregistration of the short time exposed image xS10 based on the misregistration amount  $d$ .

In this event, since the value of each pixel forming part of the long time exposed image xL10 and the short time exposed image xS10 is modulated by the color filter (Fig. 22), a pixel xL10 (i,j) on the long time exposed image xL10 and a pixel xS10 (i-dx, j-dy) on the short time exposed image xS10, corresponded by the detected misregistration amount  $d$ , do not always correspond to the same color filter. In other words, the misregistration may result in failed correspondence in color. To solve this problem, the misregistration amount corrector 127 corrects the misregistration in accordance with the following equation:

$$xS11(i,j) = xSip(i-dx,j-dy) \quad \dots\dots (21)$$

and sends a resultant short time exposed image xS11 to an image composer 20. In equation (21), xSip(i-dx,j-dy) indicates the value of a pixel at a position (i-dx, j-dy) on the short time exposed image xS10, corresponding to the same color filter as the long time exposed image xL10 (i,j), calculated from the values of neighboring pixels.

For example, as shown in Figs. 24A and 24B, assuming that a pixel on the long time exposed image xL10 (i,j) corresponds to a Ye filter with a misregistration amount  $d=(1,1)$ , xSip(i-dx, j-dy) is interpolated in accordance with the following equation:

$x_{sip}(I', j') =$

$$\frac{x_{S10}(i'-1, j'-1) + x_{S10}(i'+1, j'-1) + x_{S10}(i'-1, j'+1) + x_{S10}(i'+1, j'+1)}{4}$$

$i' = i - dx, j' = j - dy$

..... (22)

In other words, the misregistration corrector 127 corresponds to the same color filter as the long time exposed image  $x_{L10}(i, j)$ , and performs linear interpolation using the value of pixel nearest from a position  $(i - dx, j - dy)$ .

In the foregoing configuration, the misregistration amount detector 27 extracts feature points from the luminance information  $x_{Ly2}$  produced from the long time exposed image  $x_{L10}$  and the luminance information  $x_{Sy2}$  produced from the short time exposed image  $x_{S10}$ , captured with different exposure times, detects the misregistration amount candidate presenting the highest confidence level within a plurality of previously provided misregistration amount candidates  $dn$  based on the positional relationship of the respective feature points extracted from the luminance information  $x_{Ly2}$  and the respective feature points extracted from the luminance information  $x_{Sy2}$ , and sends the detected misregistration amount candidate as a true misregistration amount  $d$  to the misregistration corrector 127.

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The misregistration corrector 127 corrects the misregistration of the short time exposed image xS10 with respect to the long time exposed image xL10 based on the misregistration amount sent from the misregistration amount detector 27, and sends a resultant short time exposed image xS11 to the image composer 20. The image composer 20 composes the long time exposed image xL10 and the misregistration corrected short time exposed image xS11 to produce a single composite image x1 having a wide dynamic range.

By thus composing the long time exposed image xL10 and the short time exposed image xS10 after correcting the misregistration therebetween, the image quality will never be degraded near the edges as observed in a composite image which would be composed with misregistration present between two images.

According to the configuration described above, the misregistration of the short time exposed image xS10 is corrected with respect to the long time exposed image xL10, and then the long time exposed image xL10 and the misregistration corrected short time exposed image xS11 are composed to produce the composite image x1 to avoid a degraded image quality which would otherwise be found when two images are composed without correction, thereby making it possible to produce a natural composite image corresponding to an object to be imaged.

In addition, since the luminance information xLy2 and the luminance information xSy2 are extracted from the long time exposed image xL10 and the short time exposed image xS10,

respectively, to detect a misregistration amount  $d$  from the luminance information  $xLy2$  and the luminance information  $xSy2$ , it is possible to precisely correct misregistration even for a color image.

#### (5) Other Embodiments

While the foregoing first to fourth embodiments have been described in connection with an implementation in which the gain is corrected within the image composer 20, the present invention, however, is not limited to such gain correction. Alternatively, a gain corrector can be disposed previous to the memory 16 for storing the short time exposed image  $xS1$  to omit the gain correction performed with the image composer 20.

Also, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the short time exposed images  $xS1$ ,  $xS10$  are corrected for misregistration, the present invention is not limited to the correction to the short time exposed images. Alternatively, the long time exposed images  $xL1$ ,  $xL10$  can be corrected for misregistration.

Further, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the gain correction is performed on the short time exposed images  $xS4$ ,  $xS11$ , the present invention is not limited to such gain correction. Alternatively, the gain correction can be performed on the long

time exposed images  $xL1$ ,  $xL10$ . In this case, the value of each pixel on the long time exposed images  $xL1$ ,  $xL10$  can be divided by an exposure time ratio  $g$  calculated by the aforementioned equation (2).

Further, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the amount of misregistration is detected after the gain correction is performed on the short time exposed images  $xs1$ ,  $xs10$ , the present invention is not limited to such detection accompanied with the gain correction. Alternatively, the amount of misregistration can be detected without gain correction if pixel positions independent of the amount of exposure are used as feature points, as the zero-cross points shown in Fig. 9.

Further, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the confidential calculator 45, 68 or 119 scans the entire feature point image  $pL1$ ,  $pL11$  to  $pL14$  corresponding to the long time exposed image  $xL2$  to detect feature points and integrate the confidence levels, the present invention is not limited to the scanning of the entire feature point image. Alternatively, since feature points positioned near edges of an image are not likely to appear in the feature point images  $ps1$ ,  $ps11$  to  $ps14$  corresponding to the short time exposed image  $xs3$  due to the influence of misregistration, a range in which feature points are scanned can be limited on the feature point images  $pL1$ ,  $pL11$  to  $pL14$ , as shown



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Further, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the confidence level calculator 45 calculates a confidence level by scanning the feature point image pL1, pL11 to pL14 to detect feature points thereon, and examining whether or not corresponding feature points on the feature point image pS1, pS11 to pS14 exist at positions at which the detected feature positions are corrected, using a misregistration amount candidate dn, the present invention is not limited to the thus calculated confidence level. Alternatively, as expressed by the following equation:

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the entire feature point image pS1, pS11 to pS14 can be translated by a currently intended misregistration amount candidate dn, and the total number of feature points that match the feature points on the corresponding feature point image pL1, pL11 to pL14 in position can be employed as a confidence level cmap (dn) for the misregistration amount candidate dn. In equation (23),  $N_x$  and  $N_y$  are the numbers of pixels in the horizontal direction and the vertical direction, respectively, on the feature point image pS1, pS11 to pS14. For reference, for points (i-dnx, j-dny) which do not exist on the feature point image pS1, pS11 to pS14, the addition indicated by the aforementioned equation (23) is not performed.

Further, while the foregoing first to fourth embodiments have been described in connection with an implementation in which the maximum value detector 47 detects a misregistration amount candidate  $d_{\max}$  having a maximum confidence level within the confidence map cmap (dn) sent from the confidence level calculator 45, and employs  $d_{\max}$  as a true misregistration amount  $d$ , the present invention is not limited to this method of detecting the misregistration amount. Alternatively, as illustrated in a misregistration amount detector 200 in Fig. 26, a smoother 202 can be provided between the confidence level calculator 45 and the maximum value detector 47, such that, taking advantage of the fact that the confidence map cmap (dn) can be regarded as two-dimensional image data cmap (dx, dy) as shown in Fig. 27 which has





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composed. In this case, any of a plurality of images is assigned as a reference image, such that a misregistration amount detector and a misregistration corrector are provided to correspond to images other than the reference image and correct misregistration of the images with respect to the reference image.

Further, the foregoing first to fourth embodiments have been described in connection with an implementation in which the long time exposed image xL1 and the short time exposed image xS4 are composed to produce a signal composite image. The present invention, however, is not limited to the composition of two images, and for composing images with three or more different exposure times, the composition processing in accordance with the aforementioned equation (13) can be repeated in order from the image with the longest exposure time.

In the foregoing second embodiment, the misregistration amount detector 62 extracts four types of feature points P1 to P4 from the long time exposed image xL2 and the short time exposed image xS3, respectively. The present invention, however, is not limited to the four types of feature points, but essentially, plural types of feature points can be extracted from the images.

Also, in the foregoing second embodiment, the feature point images pL11 to pL14 and pS11 to pS14 are written into the corresponding memories 66A<sub>1</sub> to 66A<sub>4</sub> and 66B<sub>1</sub> to 66B<sub>4</sub>, respectively. The present invention, however, is not limited to such a manner of writing the feature point images. Alternatively, as is the case

of a misregistration amount detector 210 illustrated in Fig. 29, feature point images pL11 to pL14 sent from feature point extractors 74A<sub>1</sub> to 74A<sub>4</sub> can be written into a memory 212A, while feature point images pS11 to pS14 sent from feature point extractors 74B<sub>1</sub> to 74B<sub>4</sub> can be written into a memory 212B to produce multi-value feature point extraction images pL20, pS20, in which a pixel can take a value from zero to three, and the feature point extraction images pL20, pS20 are supplied to the confidence level calculator 214 to detect the amount of misregistration.

Further, while in the foregoing fourth embodiment, the luminance separators 124, 125 are provided previous to the limiter 18 and the gain corrector 21, respectively, the present invention is not limited to this configuration. Alternatively, when a zero-cross point extracted by the feature point extractor 30A shown in Fig. 8 is used as the feature point, a filter which additionally has the characteristic of removing or reducing the modulation introduced by a color filter can be used in place of the second-order differentiation type filter 35 to omit the luminance separators 124, 125.

Also, while in the foregoing fourth embodiment, the complementary color diced filter is placed in front of the CCD 122, the present invention is not limited to the placement of the diced filter, but a variety of other color filters can be placed in front of the CCD 112, such as a primary color stripe filter, in which case, appropriate interpolation processing can be performed



invention is applied, the present invention is not limited to the video camera but can be widely applied to a variety of other apparatus equipped with an imager device such as a still camera, a surveillance camera, a car-equipped camera, and so on.

According to the present invention as described above, a misregistration amount of each of images except for a reference image is detected with respect to the reference image, misregistration of each of the images except for the reference image is corrected with respect to the reference image based on the misregistration amount, and then the reference image is composed with each of misregistration corrected images other than the reference image, thereby making it possible to avoid a degraded image quality which would otherwise be produced when a plurality of images are composed without correction, and consequently produce a natural composite image corresponding to an object to be imaged.

While there has been described in connection with the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be aimed, therefore, to cover in the appended claims all such changes and modifications as fall within the true spirit and scope of the invention.